UNITED NATIONS UNIVERSITY

UNU-WIDER

World Institute for Development Economics Research

Research Paper No. 2006/27

Innovations, High-Tech Trade and Industrial Development

Theory, Evidence and Policy

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March 2006

Abstract

Innovations spur science-based trade and industrial development in a fast changing pace of globalization. Knowledge accumulation and diffusion have been increasingly recognised as fundamental factors that play an important role in long-run economic growth. This paper focuses on the long-term innovation strategy of industrial and technological development in developing countries. Growth theory, empirical evidence and several indicators of innovation have been pressed into service to draw important lessons from historical experience of the developed and newly industrializing countries for the industrial development of the developing economies. Technology development and public technology policy experience of the East Asian countries have been examined to reinvent the role of public technology policy that can be adopted to develop national innovation system to nurture and build innovative capabilities in the developing economies in the dynamic global economy.

Keywords: innovations, growth, high-technology, Asia, government policy

JEL classification: F2, O1, O3

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This study is a revised version of the paper presented at the 17-18 June 2005 UNU-WIDER anniversary conference, 'WIDER Thinking Ahead: The Future of Development Economics', directed by George Mavrotas and Anthony Shorrocks.

UNU-WIDER gratefully acknowledges the financial contributions to the research programme by the governments of Denmark (Royal Ministry of Foreign Affairs), Finland (Ministry for Foreign Affairs), Norway (Royal Ministry of Foreign Affairs), Sweden (Swedish International Development Co-operation Agency—Sida) and the United Kingdom (Department for International Development).

ISSN 1810-2611 ISBN 92-9190-795-2 (internet version)

Acknowledgements

The author is grateful to Matti Pohjola, Keun Lee, Germano Mwabu and K.J. Joseph for suggestions and enlightening discussions during the WIDER Jubilee Conference in Helsinki, 17-18 June 2005, which helped in carrying several refinements in the paper. Comments and suggestions of Robert E. Evenson of Yale University, and two anonymous referees of the conference volume, are duly acknowledged. However, the author is solely responsible for errors and omissions that remain.

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Camera-ready typescript prepared by Lorraine Telfer-Taivainen at UNU-WIDER

1 Introduction

The knowledge base in the major economies has been growing at a fast pace. Investment in knowledge accounts for about 4.7 per cent of OECD-wide GDP and the high-knowledge-based economies invest between 5.2 to 6.5 per cent of GDP in knowledge development (OECD 2001). Developed and newly industrializing countries internationally trade goods and services which are knowledge-intensive. The industrial growth patterns and competitiveness of industries across countries and over time are closely related in the globalizing world. Two distinct patterns of industrial development are clearly noticeable: developed and newly industrializing countries moved faster towards producing and exporting goods and services which are knowledge intensive; a large number of countries could not catch up and their position in the fast globalizing world is being marginalized (Lall 2004). This pattern of industrial growth can be traced from the changing roles of innovative investment patterns in industry across countries and over time. The processes of globalization have affected different innovative activities differently and thus the rise/fall of innovative investment in some industries in some of the countries. Outsourcing of industrial R&D has shifted some of the innovative activities from developed to a few developing countries. The increasing role of foreign direct investment (FDI) and direct operation of multinational corporations in production of goods and services in the developing countries has significantly influenced development/underdevelopment of innovative capabilities. Developing countries under the new international economic order have substantially reduced the role of the state in innovative investment and have promoted the dependence on either private initiatives or on FDI. Therefore, it is legitimate to inquire the changes in the pattern of industrial innovative investment on trade and industrial development which are occurring across countries and over time.

Asian countries (South East Asia, China and India) have shown dynamism, in terms of industrial development and contributing to global trade with high-tech exports, in the fast globalizing world. East Asian economies followed a standard pattern of economic transformation and achieved more than a 9 per cent growth rate during the decades of the 1980s and 1990s in the twentieth century. The industrial sector is truly the engine of growth of these economies contrary to the service sector-led economic growth in the case of other economies. The industrial growth experience of East Asia remained highly controversial on two counts. One, capital accumulation versus technical progress which of the factors that have allowed East Asia to achieve a faster rate of industrial growth. Two, the role of the state in enacting suitable policies for industrial development or the market forces which led the East Asia to succeed in economic transformation as well as in the international market. Thus Asian countries are most suitable to test new economic growth theory and draw lessons from successful public policy experience for other stagnant economies. This paper is an attempt in that direction and is organized in seven sections. Apart from the introductory section, a review of the growth theory and empirical literature is presented in Section 2. Sources and indicators of innovations across regions and continents are presented in Section 3. Section 4 contains the growth pattern of industrial R&D expenditure across major developed and developing economies. Analysis of the indicators and sources of innovations across Asian countries is presented in Section 5. The role of public innovation policy in a rapidly globalizing world economy to achieve rapid industrial development in developing countries is presented in Section 6. In the final section, we have drawn lessons from the innovative public intervention in technology development of the East Asian countries for other less developed countries in general and for South Asian countries in particular.

2 Knowledge accumulation and economic growth: theory and empirics

Technological knowledge accumulation is now being widely acknowledged and acclaimed as a source of economic growth. Differentials in the level and growth of income across countries and over time are being increasingly recognized due to knowledge accumulation differences. The evolution of the sources of economic growth can be seen through the development of the long-run theory of economic growth which has been developed after the Great Depression in the twentieth century in three waves (Ruttan 2001). The first wave was initiated by the work of Harrod (1939) and Domar (1946). Solow (1956, 1957) and Swan (1956) developed a model of long-run growth in neoclassical tradition that stimulated the second wave. More recently, the third wave was stimulated in the mid 1980s by the writings of Romer (1986) and Lucas (1988).

Modern theory of economic growth has recognized the dominant role of technological knowledge as a determinant of economic performance. The superior economic performance across countries and over time has been essentially attributed to the proportion of knowledge accumulation (Solow 1956, 1957). Knowledge accumulation and its growth have been attributed to be determined by the exogenous factors and seem to be the fundamental responsibility of the state. Thus, the agents of production are the receivers of new knowledge which is external to their circumstances. Since knowledge has global public good property and is universally accessible, therefore, the tendency is towards convergence of productivity and overall economic growth. Contrary to this, the evolutionary growth theory has recognized the cost of acquiring new knowledge as well as benefits of accumulation of knowledge which is path dependent. This signifies that knowledge accumulation and generation not only is endogenous but also assumes capability building. These capabilities ultimately allow economic agents of production to reap the benefits of being leaders in innovations that matter in the markets. Therefore, the prediction of the theory is that the level of development and growth is historically determined. Those countries and industries which invest more in knowledge accumulation and generation will stay ahead compared with others (Ruttan 2001).

New growth theory, which is popularly known as ‘endogenous growth theory’, not only recognized the importance of knowledge accumulation for economic growth but successfully modelled the commercially oriented innovative investment. Sources of knowledge generation were fundamentally endogenous and were driven by the commercial interest. An important characteristic of this kind of economic thinking is that knowledge accumulation and generation give birth to increasing returns to scale of an important scarce factor that is capital accumulation. However, knowledge accumulation in these kinds of models itself is susceptible to diminishing returns to scale (Romer 1986). Another property of endogenous knowledge accumulation is that it is non-rival and partially excludable and thus generates significant amount of externalities. It has been argued that knowledge is expensive to develop but is inexpensive to use which underline the importance of scale effects. The value of knowledge increases with the increase in the size of the market (Romer 1993, 1997). Thus, the model predicts that those who invest more in knowledge generation and accumulation will grow at a faster rate and those who do not will continue to persist and stay backward.

An important implication of this kind of economic thinking is that knowledge exhibits public good property which is not completely appropriable through market transactions by the private agents of production. Thus, private agents of production have a tendency to underinvest and consequently underline the role of public policy to address this gap. The other important implication of Romer-Lucas stimulated endogenous growth literature is that there is incentive to enhance the quality of human and physical capital that has a capacity to raise permanently economic growth rate and level of per capita income. Thus, the activist technology policy pursued by the government to enhance quality of human and physical capital has a capacity to permanently raise not just the per capita income but the long-run rate of economic growth (Verspagen 1992).

Empirical literature, which draws inspiration from endogenous growth models, on the knowledge generation and diffusion—both domestic and international—has grown recently by leaps and bounds. A seminal contribution to empirical literature which establishes the relationship between total factor productivity and stocks of measured knowledge has been made by Coe and Helpman (1995). The authors have selected OECD countries and Israel to empirically verify the relationship between superior economic performance and cumulated stock of technological knowledge. They have also established the interdependence, in terms of technological knowledge, among the developed countries and technological knowledge of the trading partner for smaller economies has been more important compared to that of the domestic knowledge. Trade has a capacity to transmit superior knowledge across national boundaries that matter for economic growth. However, the domestic knowledge in the large countries has recorded higher elasticity than that of the foreign knowledge. These results were confirmed while extending the scope of the study to include 77 developing countries in the sample (Coe et al. 1997). An important conclusion which emerged from the above mentioned study is that trade is the most important vehicle of knowledge diffusion across countries, and developing countries do benefit substantially from the innovations generated by the industrially advanced countries.

This revealing new evidence generated controversy and scepticism with regard to the validity of the evidence and thus resulted in a spurt in empirical literature on foreign knowledge spillovers (Keller 2004; Navaretti and Tarr 2000). The sceptics re-estimated after introducing the refinements in the Coe and Helpman estimates for the sample of OECD countries but endorsed the results more empathetically.[1] Contrary to this, Evenson and Singh (1997) in a sample of eleven Asian countries during the period 1970-93 found higher elasticity of domestic knowledge stock compared to foreign. However, East Asian countries did have higher impact of foreign knowledge transmitted through international trade. Somewhat similar empirical results were reported by Kim (2000) from the analysis of the East Asian countries during the period 1971-93. Transmission of technological knowledge to developing countries through trade literature has almost completely ignored the role of domestic technological capabilities which facilitates the adaptation of foreign knowledge barring a few.

FDI, at least in theory, has been widely recognized as the most important source of diffusion of technological knowledge across national boundaries. Flexible manufacturing system has opened up ample opportunities, where a firm superior in technology can subcontract some of its operations to save costs and in the process can also transfer technical know-how to local firms. This is being done to maintain the required quality control of the processes of production of the local firm. Therefore, it was expected that substantial learning can occur and improve productivity of domestic firms. However, recent studies do not confirm the expected relationship between productivity growth and knowledge diffusion through FDI.[2] A more recent literature does report from micro empirical studies some positive relationship for developed countries.[3] Domestic firms which have substantial technological capabilities are able to catch knowledge spillovers and raise productivity and those who do not have capabilities have negative productivity effects.[4] FDI at the most can supplement the domestic technological capabilities, but alone can not engineer innovations in the host country. Knowledge spillovers across countries and industries, as the major source of growth predicted by the endogenous growth literature, are fundamentally dependent on domestic technological capabilities and the stage of industrial development. As soon as a country's economic agents of production reach close to technology frontier, knowledge spillovers as a source of productivity growth cease to exist because knowledge at that level becomes more and more tacit (Stiglitz 2003; Singh 2004a).

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[1] Keller (1998); Lichtenberg and Potterie (1998).

[2] Keller (2004); Hanson (2001); Gorg and Greenaway (2002).

[3] Keller (2004).

[4] Girma (2005); Siddharthan (2004).

3 Sources and indicators of innovations in the global economy

There are two main indicators of measurement of innovations that is input and output. Research and development expenditure is the input measure of innovation. Patents registered, scientific research papers published in recognized international journals and high-tech trade are the output measures of innovations. These indicators which generate innovations and outcomes that can be realized through commercial operations are presented in Table 1. The generation of innovations has been widely acknowledged as dependent on the innovative investment in the global economy. Total R&D expenditure incurred in the global economy has increased from 409.8 billion PPP dollars in 1990 to 755.1 billion PPP dollars in 1999-2000. Industrially advanced countries expended 367.9 billion PPP dollars in 1990 which was nearly 90 per cent of the total global R&D expenditure. The expenditure on R&D increased to 596.7 billion PPP dollars in 1999-2000 but the relative share comes out to be 79 per cent of the global R&D. This clearly shows that despite the absolute rise in the R&D expenditure of the developed countries, their share in relative terms has dwindled 11 percentage points during the last decade of the twentieth century. Developing countries, on the other hand, increased innovative efforts and raised their relative share from 10 per cent in 1990 to 21 per cent in the year 2000. This trend clearly shows reduction of concentration of innovative efforts in the still highly inequitable knowledge-based economy. The rise in the share of R&D of the developing countries in the global R&D is mainly due to the big push in innovative efforts of East Asian countries.

Table 1: Sources and indicators of innovations in developed and developing countries

Region/Year	R&D expenditure (billion PPP$) 1990	R&D expenditure (billion PPP$) 1999/2000	Scientific and technical journal articles 1999	Technology and license fees received (billion $) 2002	Patent application filed by residents in 2001	High-tech exports (billion $) 2000	FDI outflows (billion $) 2001
World total	409.8	755.1	528,627	79.61	939,267	998.00	630.30
	(100.00)	(100.00)	(100.00)	(100.00)	(100.00)	(100.00)	(100.00)
Developed countries	367.9	596.7	451,877	78.21	855,902	881.00	470.10
	(89.77)	(79.02)	(85.48)	(98.24)	(91.12)	(88.30)	(74.58)
Developing countries	42.0	158.4	76,750	1.40	83,365	117.00	115.20
	(10.25)	(20.98)	(14.52)	(01.76)	(08.88)	(11.70)	(18.28)
North America	156.4	281.0	185,492	45.88	197,238	267.00	197.3
	(38.16)	(37.21)	(35.09)	(57.63)	(21.00)	(26.75)	(31.30)
Latin America & Caribbean	11.3	21.3	12,018	0.41	7,383	27.00	69.10
	(02.76)	(02.82)	(02.27)	(00.52)	(00.79)	(02.71)	(10.96)
Africa	5.2	5.8	3,612	0.06	207	2.62	8.5
	(01.27)	(00.77)	(00.68)	(00.07)	(00.02)	(00.26)	(01.35)
Asia	94.2	235.6	22,824	0.17	30,722	130.08	36.5
	(22.99)	(31.20)	(04.32)	(00.21)	(03.27)	(13.03)	(05.79)
Europe	138.8	202.9	122,017	10.96	128,297	-	236.6
	(33.87)	(26.87)	(23.08)	(13.77)	(13.66)		(37.54)

Source: UNESCO (2004); World Bank (2004); Singh (2004b).

Table 1 clearly shows that the hub of innovative activities is North America which has highest R&D intensity. The USA is the largest both in absolute level and in relative terms so far as innovative investment is concerned. The Asian continent is also emerging as a hub of both economic and innovative activities. R&D expenditure increased from US$94.2 billion in 1990 to US$235.6 billion in 2000, which is slightly more than a two-fold increase within a decade. Asian R&D expenditure increased faster compared to other regions and improved its relative position from third to second in the global reckoning. Asian countries accounted for 23 per cent of the global innovative investment expenditure in 1990 which increased to 30.9 per cent in 2000. Europe lagged behind because of decline in R&D expenditure in the East European countries. Two noteworthy facts here are: one, South East Asia and China substantially raised innovative investment expenditure and globally commercial/private sector stakes in innovative investment increased substantially; and two, R&D intensities either slightly declined or remained stagnant across regions except in North America where it improved slightly.

The innovative efforts over a period of time have developed a system in which economic agents of production participate, learn to use, and acquire knowledge. This process has not only given birth to a national system of innovation, but also nurtured economic agents of production to be pioneers in exploiting new opportunities and strongly built international comparative advantage. Therefore, there is a positive relationship between the innovative investment and the outcomes of innovations. Industrially advanced countries not only spend higher proportion of R&D resources but also publish more than the 85 per cent of the global scientific papers published in scientific and technical journals. This clearly shows that national innovation system takes time to develop and the innovative outcomes lagged behind compared to the innovative investment.

Developing countries increased their share in innovative investment, however, the proportion of scientific and technical papers published in the journals remained substantially lower, that is, the share of R&D expenditure is 21 per cent and share of papers published is nearly two per cent in 1999. The share of North America and Europe for published scientific and technical papers in journals was 35 per cent and 23 per cent respectively in 1999. However, Asia published only 22,824 scientific and technical papers, which is about 4 per cent of the global figure (Table 1). This clearly brings out the concentration of production of new ideas in terms of scientific and technical papers in the developed countries. Thus, the contribution made by the developed countries towards the global pool of knowledge is amazingly high and the expansion of knowledge frontiers is largely conditioned by the evolution of the national innovation systems which is highly dependent on the history of innovative investment. It is expected that the contribution towards the expansion of new knowledge will be substantial from the Asian continent due to the speed at which resources devoted to innovative investment have increased in the recent past.

New scientific and technical knowledge which has commercial utility is being increasingly patented for producing goods and services to enhance comparative advantage of the nations. This indicator of innovation clearly shows the concentration of patent applications filed in the USA patent office by the developed countries. Out of total patent applications filed in 2001, the developed countries accounted for 91 per cent of global patent applications (Table 1). The concentration of innovations in developed countries further increases to 94.3 per cent if we take USA patents registered from 1977 to 2000 (Singh 2004b). However, the share of the developing countries in patenting of new ideas is not only meagre but the extent of the conversion of patent to commercial innovations may also be small. Even the conversion ratio of patent to innovations within the USA economy in 1982 was 57 per cent in Silicon Valley, 35 per cent in Boston and 0.3 per cent in Albany/Schenectady/Troy (New York), which clearly shows wide variations of patent to innovations conversion ratio across regions (Branscomb 2004). It is important to note here that patents have been largely concentrated in North America; Europe and Asian countries have filed just 3.27 per cent of the global patent applications filed in 2001.

The fundamental aim of commercially oriented innovations is to perpetuate and enhance international competitive advantage so that new innovations can be expanded and exploited globally. The theory of international trade leads us to expect an international division of labour that the leaders of innovations (developed countries) export high technology goods and services, and the laggards (developing countries) continue to export raw materials and low-skill-based goods and services in the international economy (Archibugi and Pietrobelli 2003). The empirical literature on knowledge growth and trade specialization has clearly established the relationship between innovations and international trade specialization (Malerba and Montobbio 2000).

High technology trade has grown at a faster rate during the last quarter of the twentieth century. Total global high-tech trade in 2000 was US$998 billion, that is 20 per cent of manufactured goods and services traded internationally (World Bank 2003). It is important to note here that high technology international trade is originating from the developed countries and is quite close to the prediction of the widely held wisdom of international trade theory. The share of high-tech trade of the developed countries in 2000 was 88.3 per cent of the total global high-tech international trade in manufactured goods. However, developing country high-tech-based international trade was of the order of US$117 billion in 2000, nearly 12 per cent of the global high-tech-based international trade in manufactured products. Since a substantial amount of inter- and intra-industry trade theory and empirical evidence suggests that international trade is governed by multinational corporations, it may be that the high-tech trade originating from developing countries could actually belong to innovative firms of developed countries producing in developing countries.[5] North American countries are predominant as far as high-tech international trade is concerned and account for nearly 27 per cent globally. Newly industrialized countries have been improving their position in international high-tech trade and accounted for 13 per cent of the global figure in 2000 (Table 1). Growth experience of global international trade of manufactured goods and services reveals during 1985-2000 that developing countries recorded higher growth rates compared to developed countries (Table 2). The general pattern from the estimated growth rates of international trade reveals that high-tech exports increased at a faster rate compared to the resource-based medium- and low-technology-based exports. Exports of developing countries increased during 1985-2000 at a faster rate compared to developed countries.

Table 2: Growth of high-tech and other manufactured exports across developed and developing countries (1985-2000)

Categories/Regions	World	Developed Countries	Developing Countries
Resource based	6.60	5.18	11.00
Low technology	8.85	6.86	11.69
Medium technology	8.45	7.57	13.36
High technology	13.19	11.13	19.21

Source: adapted from Lall (2004); and World Bank (2004).

FDI has been advocated as a panacea for the ills of the less developed countries. Apart from filling the gap of investment resources, FDI is also expected to bring in new management and technical innovations as well as new practices which help push up efficiency levels of domestic firms. Global FDI inflows decreased by 41 per cent in 2001, and were US$651 billion in 2002. The share of global FDI outflows originating from developed countries was nearly 75 per cent in 2001 (Table 1). European and North American countries contribute largely to the global FDI outflows. A noteworthy feature of global FDI inflows is that 72 per cent of the flows are being received by the developed countries themselves. Developing countries are receiving just 25 per cent of global FDI flows. Asia and the Pacific countries are receiving more than 51 per cent of developing countries FDI inflows. Among the Asian countries, China alone has been receiving 44 per cent of Asian and Pacific FDI inflows. This evidence clearly shows the high degree of concentration of FDI inflows in certain locations, and thus in general can be considered as a definite source which can fill the gap of developing economies investment requirements. The relationship of FDI and innovations does not seem to hold as multinational corporations do not locate strategic R&D away from home locations. They do undertake some R&D in developing countries, but not much. In the mid 1990s R&D performed in developing country affiliates as reported by USA-based

5 Amable (2000); Urata (2001).

multinational corporations came to 8 per cent of total R&D of the affiliates; just one per cent of parent company R&D. The R&D expenditure incurred by multinational corporations (MNCs) away from home location at the most is adaptation of the existing products to the local conditions.[6] Even the technological spillovers to local firms benefits only if the firms have enough technological capabilities to catch up the complex and tacit elements of technological knowledge. Otherwise the presence of FDI in developing countries adversely affects the technological performance of local firms.[7]

Royalty payments received in terms of technology transfer is an important indicator of technology-generating countries. Global technology and licensing fees from technology transfer was nearly US$80 billion. The share of developing countries of the global revenue generated from technology and licensing fees in 2002 was more than 98 per cent. Thus, it shows a very high degree of concentration of revenue received. This implies that developed countries produce technologies, and developing countries are receivers of technological knowledge and know-how. On the whole, indicators, both input and output, of global innovations reveal a high degree of concentration of innovations in the developed countries.

4 Trends in industrial R&D expenditure across countries

Commercially oriented innovative investment has largely been done by the industrial sector of the countries with a view to securing profits from the markets both domestic and international. The industrial research and development expenditure of the selected 17 countries for analysis (Table 3) has grown steadily over the period of 1977 to 2000 at rate of 3.87 per cent per annum. Total resources expended by these countries increased from PPP US$117.4 billion in 1977 to PPP US$289.6 billion in 2000. It is important to note here that more than 53 per cent of industrial expenditure was incurred by USA industry in 1977. US industrial R&D expenditure has steadily grown at 2.64 per cent per annum and absolute expenditure increased from US$62 billion in 1977 to US$118 billion in 2000. USA industries dominated the high-tech markets, however the relative share of industrial R&D dwindled to 40.78 per cent in 2000.

Industrial R&D expenditure of three European countries recorded in Table 3 negative trends during the period 1977 to 2000. These are Ireland (-4.10 per cent), Italy (-1.43 per cent) and the UK (-0.55 per cent). Deceleration of industrial R&D expenditure has substantially reduced the relative shares and position of these three countries among the 17 countries during the period 1977-2000. Shift factors may have played an important

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[6] UNCTAD (1999: 195-228); Evenson and Westphal (1995).

[7] UNCTAD (1999); Siddharthan (2004)

Table 3: Growth and structure of industrial R&D expenditure across countries

Country	1977 million PPP$ at 1995 prices	Rank	2000 million PPP$ at 1995 prices	Rank	Trend growth rate 1977-2000
USA	62,891 (53.54)	1	118,135 (40.78)	1	2.64
Japan	8,414 (07.16)	5	66,996 (23.13)	2	9.52
Australia	643 (00.55)	11	1,728 (00.60)	14	5.90
Canada	1,325 (01.13)	7	5,581 (01.93)	7	5.71
Denmark	298 (00.25)	15	1,196 (00.41)	15	6.66
Finland	286 (00.24)	16	2,461 (00.85)	13	8.78
France	9,870 (08.40)	3	16,322 (5.63)	4	2.30
Germany	8,484 (07.22)	4	32,688 (11.28)	3	5.09
Ireland	824 (00.70)	10	292 (00.10)	17	-4.10
Italy	8,282 (07.05)	6	5,315 (01.83)	8	-1.43
Netherlands	1,248 (1.06)	8	3,513 (01.21)	11	4.28
Norway	308 (00.26)	14	586 (00.20)	16	3.06
Spain	1,083 (00.92)	9	2,669 (00.92)	12	4.74
Sweden	199 (00.17)	17	5,127 (01.77)	9	6.54
UK	12,331 (10.50)	2	12,840 (04.43)	5	-0.55
India	607 (00.52)	12	4,828 (01.67)	10	7.82
South Korea	360 (00.31)	13	9,781 (03.38)	6	16.51
Total	117,451 (100.00)	-	289,657 (100.00)	-	3.87

Note: Figures in parentheses are percentages.

Source: OECD (2002); Government of India (2003); KITA (2002).

role in reducing the industrial R&D expenditure of UK and Italy, that is, there appears to be a race to transform the economies from producers of industrial goods to knowledge-based economies. Thus the substitution effect seems to have played dominant role, but relocating industrial activities to cheaper labour cost locations could be an explanation. Ireland has chosen to be dependent for industrial development on the FDI. All other European countries have shown rising trends in their industrial R&D expenditures. It is significant to note that the European countries, who have expended smaller amounts of R&D in industry beginning with the initial period, have shown faster rates of industrial R&D expenditure during the period of study. This clearly shows trend towards convergence across the European economies. Overall R&D expenditure has been empirically tested and an overall trend was found of convergence across European regions. However, private R&D expenditure has shown clearly wide dispersion across European economies (Martin et al. 2004).

Asian economies have surprisingly shown very high industrial R&D expenditure growth during the period 1977-2000. Japan's industrial R&D expenditure increased at a rate of 9.52 per cent per annum during the study period. Its relative position improved from fifth to second with shares jumping from 7.16 in 1977 to 23.13 in 2000. South Korea recorded highest rate of growth in industrial R&D at 16.51 per cent per annum. This enabled the country's industrial R&D expenditure relative share to improve from a mere 0.31 per cent in 1977 to 3.38 per cent in 2000, jumping in rank from thirteenth to sixth position in the last quarter of the twentieth century. India's industrial R&D expenditure has grown at a rate of 7.82 per cent per annum and could marginally improve its relative share and position (Table 3). A noteworthy feature that emerges from the foregoing analysis is that the three Asian economies have shown substantial growth in industrial R&D expenditure.

So far as sources of industrial R&D expenditure are concerned, there is a trend toward a greater role of the private sector across countries and more so in the case of East Asian economies. The role of the private sector in India's industry has increased substantially. The share of private industrial R&D expenditure, which was nearly 55 per cent in 1980-81, has increased substantially during the period of fast globalization to 81 per cent. The real public sector R&D expenditure has decreased and recorded negative growth rate during the last decade of the twentieth century (Singh 2001). This tells about the role of state in downsizing the public sector economic activities. India's high-tech draw in a substantial amount of innovative investment amounting to nearly 70 per cent of the total industrial R&D expenditure during 1998-99.[8] Intensity of industrial R&D is substantially higher in the private sector high-tech industries compared with the public sector. However, defence-related industries have high R&D expenditure compared with civilian industries. Private sector industrial R&D is concentrated in the Maharashtra state (52 per cent) and Karnataka state is continuously able to corner a substantial proportion of public sector industrial R&D (36 per cent). The structure of India's industrial R&D expenditure is quite shallow and highly concentrated in few industries and within two states.

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8 Government of India (2003).

The industrial R&D expenditure pattern has a bearing on industrial activities. During the last quarter of the twentieth century, a rapid rise in innovation investment caused a significant shift in the structure of industrial activities in the global economy. The industrial production and trade in high-tech activities has expanded at a faster rate compared with other manufacturing activities. High-tech industrial performance is highly correlated with high-tech R&D expenditure. Japan has the highest R&D expenditure in high-tech industrial activities. Japan and Korea are ranked first and seventh respectively among the 26 countries examined by Lall (2004), exporting high-tech products above US$5 billion in 1998. Other Asian countries which figure among the high-tech R&D expenditure per unit of exports are Taiwan (18th), China (19th), Singapore (21st), Malaysia (23rd), Hong Kong (24th), Thailand (25th) and the Philippines (26th). The rest of the ranks, in terms of high-tech R&D per unit of high-tech exports, were occupied by developed countries.

There are two distinct sets of countries which are engaged in high-tech manufacturing activities: (1) countries where the high-tech industrial R&D expenditure per unit of exports is being incurred by the domestic firms (Japan comes under this category); and (2) countries where the high-tech industrial R&D expenditure is dependent on transnational corporations for their high-tech industrial production and exports (Malaysia, Thailand and the Philippines come under this category). It is important to note here that there exists a strong positive relationship between domestic R&D expenditure and industrial performance. Lall (2004), using data of 75 countries for 1985 and 1998, has provided consistent and robust estimates from the econometric model for the relationship between the domestic R&D expenditure and industrial performance. UNCTAD (2005) has found a high degree of correlation between economic growth and domestic innovation capability index. This suggests that innovative investment which generates domestic innovation capabilities is a precondition for the transformation of industrial structure and sustained economic growth of a developing economy.

5 Sources and indicators of innovations across Asian countries

The differences in innovation investment are substantial across Asian countries. South Asian countries are far behind in innovative investment efforts compared with the East Asian Countries (Table 4). Indicators of technology development and the technological outcomes, which are presented in Table 4, clearly point out that Taiwan and South Korea have moved ahead. These countries systematically built domestic capabilities over the last quarter of the twentieth century. South Korea is highest investor in innovation activities, incurring 3.0 per cent of GNP on R&D. Next to Korea is Taiwan with a R&D intensity of 2.08. Taiwan is leading in technology development and is globally ranked number 2 in terms of technology index. Science and technology-based manufactured exports from Taiwan constitutes 39 per cent of total manufactured exports. Singapore is unique in terms of succeeding in technology development on a model dependent heavily on FDI and is also able to combine domestic efforts to climb the technological ladder. Its investment in R&D is 1.84 per cent of GDP, and 76 per cent of the manufactured exports are high-tech. Its global technology development ranking is 17th. Malaysia is also quite successful in exporting high-tech manufactured goods and services which are solely dependent on FDI. However, domestic technological capabilities could not grow in the absence domestic innovative capabilities. Lately, China has raised substantially the investment in innovations and crossed the one per cent mark of GNP. The success of China in attracting FDI and international trade has been widely recognized, however the country's global technological ranking based on technology index is 63.

Table 4: Indicators of technology across South Asia and East Asian countries

Country	Share of R&D in GNP	High-tech exports as % of man. exports 2002	Technology index rank 2002	FDI in million US$ 2002
Bangladesh	0.03 (2000)	0.00	79	47
India	0.60 (2000)	5.00	57	3030
Pakistan	0.92 (1987)	1.00	-	57
Sri Lanka	0.3	1.00	67	242
Indonesia	0.07 (2000)	16.00	65	-1513
Rep. of Korea	3.0 (2002)	35.00	18	1972
Malaysia	0.42 (2000)	59.00	26	3203
Singapore	1.84 (1999)	63.00	17	6097
Taiwan	2.08 (2000)	39.00	2	-
Thailand	0.16 (2001)	32.00	41	900
China	1.1 (2002)	23.00	63	49,308

Note: Figures in parentheses are the year of availability of R&D expenditure.

Sources: World Economic Forum (2003); UNDP (2004); World Bank (2004).

Other East Asian countries are moving ahead in terms of raising technology as a factor in their respective economic development. Still, they lag behind as far as generating capabilities for development of technological knowledge is concerned. The international technological rankings of Malaysia, Thailand and Indonesia are quite low. Differential performance of East Asian countries in technology development clearly points out that there is no substitute of systematically building domestic technology development capabilities. FDI can perpetuate technological dependence and domestic agents of production continuously upgrade and adopt technologies developed elsewhere. This in the long run depletes resources and cripples capabilities to become leaders in innovations because technology import involves substantial costs. The fundamental lesson obvious from successful East Asian countries—South Korea and Taiwan—is that strategic state intervention in enhancing innovative investment along with a selective/restrictive role of foreign direct invest helps in building national innovation systems.

The East Asian success in technology development allows us to discern two distinct strategies. First, the international trade in high-tech products and industrial growth remained heavily dependent on FDI. The countries which followed this path are Malaysia, Thailand, Indonesia and the Philippines. Technological ranking and domestic efforts in these countries have remained quite weak. National innovation systems, which increase competitiveness of domestic firms, remain quite fragile because domestic governments have relied more on foreign capital for technology. Recently, these governments have realised that without building national innovation system, despite using foreign sources of innovations more judicially, technology development and sustainability of industrial growth is not possible. Therefore, efforts have been stepped up to provide incentives to domestic firms to be innovative with better management of technology transfer through policy to spur local innovations.

Second, South Korea and Taiwan from a very early stage have systematically started building their national innovation systems and have not relied purely on FDI. FDI was kept at arm's length, but domestic firms were nurtured and encouraged by the government to succeed in the international market. These economies developed early on high quality human capital for simulative and adaptive learning capabilities for reverse engineering, creating a network of science and technological institutions that helped them understand the complex process of technological innovations. The later strategy for moving up the technology ladder has recently gained recognition of the role of technology policy in the fast pace of globalization.

South Asian countries are slowly surging ahead on the technological ladders. India has been recognized as the tenth largest spender in absolute level innovation activities and is the most sought after place for location of R&D centres from the multinational corporations. When we look at hard data, India is ranked 57th according to technology development index among the 80 nations for which comparable science and technology statistics are available. India's share of R&D in GNP was just 0.6 in 2000. The decline in R&D intensity is attributed essentially to two factors. One, the faster rate of growth of national income during the 1990s. Two, the government's contribution in R&D spending declined/stagnated in the wake of controlling the fiscal deficit. However, the science and technology-based share of manufactured exports has increased continuously. The share of high-tech manufactured exports is 5 per cent. When we compare India's share of high-tech exports with East Asian countries the achievement is miniscule. Despite this, India is well recognized globally in the pharmaceutical as well as information and communication technology-based products and innovations.

The other major country in the South Asian region is Pakistan, which is a globally recognized nuclear power. From the civilian technology development point of view, its international recognition and contribution seems quite low. Pakistan's share of high-tech manufactured exports just 1 per cent. Another important indicator of technology development is the workforce engaged in R&D activities. Researchers engaged in R&D are 69 per population million which is quite low compared with other South Asian countries (Sri Lanka and India employed 191 and 157 researchers per million respectively). FDI flow, which is considered important source of technology transfer, is quite low in general in South Asian countries. Pakistan received US$57 million in FDI in 2000, which again is low compared with Sri Lanka and India. R&D intensity is nearly 1 per cent of the GNP of Pakistan which is much higher compared with other South Asian countries. Industrial enterprises in Pakistan hardly do any formal research and development expenditure (Lall 2000).

6 State and innovations in the fast changing global economy

East Asian economies surged ahead in the transformation process and succeeded in industrializing their economies as well as building innovation capabilities during the last quarter of the twentieth century. The emergence of East Asia as a hub of economic activity generated controversy with regard to whether governments or markets were the central factor in the successful economic transformation. However, the early attempt to describe the government's innovative role to enact interventionist policies which led private agents of production to succeed in the fast pace of globalization has been described as minority view.[9] It is important to note here that the 1997 East Asian crisis has changed the thinking among economists and international agencies with regard to the role of state in policy making and conducting development programmes. The 1997 crisis severely affected the stability of economic growth in general and innovative outcomes in particular of the region's economies, which has led to the renewal of the role of the state in terms of good governance.

Stern (2004) has recently emphasised that one important policy lesson which can be drawn from the five decades of development experience is that the state and markets complement each other. The *World Development Report 1998*[10] clearly identified the role of the government in developing countries to develop capabilities to generate knowledge at home along with providing help to domestic agents of production to take advantage of the large global stock of knowledge. It is significant to note here that

[9] Wade (1990); Srinivasan (1995).

[10] World Bank (1998).

UNDP has gone ahead in terms of identifying knowledge gaps existing between developed and developing countries and articulated the arguments against the strict intellectual property rights regime enacted and implemented by the WTO. Furthermore, UNDP has not only suggested an innovative and fundamental role for the governments of the developing countries in generating capabilities that matter for knowledge development, but has also identified knowledge as a global public good and the role of the international community in reducing the knowledge gaps.[11]

Apart from making suitable public innovation policies to strengthen national innovation systems, the governments of developing countries should also strive hard to seek co-operation amongst themselves as well as with the international institutions and agencies to negotiate in the WTO framework. Specifically, the negotiations should be with regard to MNC operations in their markets. They should also assess losses of domestic firms and seek compensation, using that to create capabilities to strengthen innovative infrastructure at home. The two-step strategy suggested above will go a long way to make capable domestic agents of production to catch up the spillover effects created by international capital and fill the knowledge gap for sustained economic growth.

7 Conclusions

The analysis of sources and indicators of innovations across countries and regions clearly shows some decrease in the concentration of innovations in the developed countries. East Asia has emerged as innovative region of technology development, with numerous lessons for developing countries in general and South Asian countries in particular in a fast globalizing world economy. The foremost lesson which should be learnt from the East Asian experience to succeed in the global economy is to reinvent the role of state to strengthen the national innovation institutional system. The developing countries are currently engaged in economic reforms to reduce the role of the state and provide larger space to market forces, which essentially make the state scarce in economic activities. This strategy of making the state scarce in developing countries suffers from the drawback of substitutability of the state and the market and reduces the competitiveness of the domestic agents of production in the international economy. It is important to note here that intervention of the state in a fast globalizing world economy is more difficult but at the same time is crucial and strategic. Therefore, reinventing the role of government policy in crafting national innovation institutional arrangements for building and strengthening competitive advantage is direly needed.

The East Asian economies have grown in an environment of import substitution and lax intellectual property regimes which are no longer available to developing economies. Intellectual property regimes enacted and imposed by the WTO have been restricting

[11] UNDP (2001); Stiglitz (1999).

developing economies put into place national innovation systems with proven adverse effects on global innovations and more particularly least developed countries (Grossman and Lai 2004; Helpman 1993). Developing country markets are invaded by multinational corporations without contributing towards generating domestic innovation capabilities. The role of international institutions is to evolve policies which should decrease the knowledge gap through imposing conditions on multinational corporations to contribute in an equal measure the percentage of sales revenue expenditure on R&D in the host country as in the home country.

The reduction of fiscal deficits under the umbrella of reform programmes gives an easy option for developing country governments to cut down expenditure on institutions which are the backbone of economic development such as education, health and infrastructure. Further, curtailing support to the R&D institutions—public and private—has a capacity to weaken the institutions which from a long-term perspective have great importance for economic growth and welfare. The right combination of state and market which delivers long-run growth is the correct strategy, rather than going from one extreme to another which in the past has introduced instability and blocked potential.

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